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TEMPORAL VARIATION OF GROUND WATER QUALITY IN CENTRAL GODAVARI DELTA AND ITS SIGNIFICANCE IN HYDRODYNAMICS OF THE AREA

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ABSTRACT

Central Godavari Delta is a Crop Intensive rice bowl of Andhra Pradesh. The present study area covers 16 mandals of East Godavari District of Andhra Pradesh. To study the temporal variation of Chemical Quality in terms of Electric Conductivity, 48 key observation wells were established and monitored the electric conductivity in the field. This shows a wide variation depending on the rainfall occurrence in the preceding season. Due to the less availability of surface water either in the form of rainfall, or in the form of canal water in the tail ends of the command area, farmers use ground water through filter points. Because of the ground water abstraction in the area, the fresh water - saline water interface was disturbed and the quality of ground water was deteriorated in the water stress periods. Hence, there is an urgent need for monitoring the fresh water - saline water interface, by constructing a purpose built observation wells with predefined monitoring parameters of level and quality with reference to depth. And, to assess the interface on a regular basis and prepare more robust ground water management plans for this area.

KEYWORDS: Fresh Water, Saline Water & Ground Water

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Original Article

INTRODUCTION

Water chemistry plays a key role in understanding the ground water quality, and this aspect is not completely understood so far. Although the variation in water chemistry is purely natural and entirely random, water with high amounts of different unwanted chemical elements may prove fatal to the life on earth. No doubt, the chemistry of groundwater is exceedingly complex, but information gathered on various factors can indicate a large extent of the groundwater quality of a specific area or a particular place.

This paper presents an account of the chemistry of groundwater based on the data obtained and analyzed from the study area. Chemical characteristics of the ground water determine the usefulness of its consumption for different purposes such as domestic, commercial and industrial. Hence, investigations leading to the ground water chemistry assume high significance as they unrevealed various factors regarding its quality, velocity and direction of its movements. Earlier studies indicate that the chemical composition of groundwater depends mainly on factors like geology, soils, biological process, topography and climate (Davis and DeWiest 1966, Todd 1980). Following the format used in standard hydro geological presentations, a brief background of the general chemistry of individual elements in the study area is given here, which facilitates better understanding of their behavior in

aqueous phase.

Groundwater is one of the earth's most vital renewable and widely distributed resources, as well as an important source of water supply throughout the world. The quality of water is a vital concern for mankind, since it is directly linked to human welfare. Groundwater can become contaminated naturally, or because of numerous types of human activities; residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality (Jalali, 2005a; Rivers et al., 1996; Kim et al., 2004; Goulding, 2000). Quality of water is as important as the availability of water, because it is directly related to health and the environment (Hari Krishna et al., 2013).

Contamination of groundwater can result in poor drinking water quality, loss of water supply, high cleanup costs, high costs of alternative water supplies, and/or potential health problems. A wide variety of materials have been identified as contaminants found in groundwater. These include synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radio nuclides (Fetter, 1999). The importance of water quality in human health has recently attracted a great deal of interest. In developing countries like India, around 80% of all diseases are directly related to poor drinking water quality and unhygienic conditions (Olajire and Imeokparia, 2001; Prasad, 1984).

Groundwater is a valuable natural resource that is essential for human health, socioeconomic development, and functioning of ecosystems (Humphreys, 2009; Steube et al., 2009). In India, severe water scarcity is becoming common in several parts of the country, especially in arid and semi-arid regions. The overdependence on groundwater to meet ever-increasing demands of domestic, agriculture, and industry sectors has resulted in overexploitation of groundwater resources in several states such as Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh, Tamil Nadu, among others (CGWB 2006; Garg and Hassan, 2007; Rodell et al., 2009).

Usually, various chemical constituents of water occur as dissociated particles or ions. The chemistry of groundwater in the present area of investigation with respect to some major elements as well as their chemically related properties has been determined, using standard laboratory procedures. Totally 48 groundwater samples were collected along with groundwater levels.

Study Area

The Central Godavari Delta is part of East Godavari district, Andhra Pradesh and lies in between 81°40' and 82°25' East longitudes and 16°15' and 17°00' North latitudes and is part of the well known Konaseema Region. The study area is bounded by the Bay of Bengal in the east and in the south, where as in the North, it is bounded by the river Gautami Godavari and in the west by the river Vasishta Godavari. The study area is covered by 16 mandals. The administrative divisions of the study area are given in Table 1. The administrative Divisions of the area are shown as Figure 1.

Table 1: Administrative Divisions of the Area under Study

S No	Mandal	No. of Revenue Villages	No of Hamlets	No of Gram Panchayats	No of Towns	No of Municipalities/ Municipal Corporations
1	SAKHINETIPALLI	8	9	16		
2	MALIKIPURAM	11	8	20		
3	RAZOLE	13	11	16		
4	MAMIDIKUDURU	17	13	18		
5	P.GANNAVARAM	18	63	20		
6	RAVULAPALEM	11	20	12		

S No	Mandal	No. of Revenue Villages	No of Hamlets	No of Gram Panchayats	No of Towns	No of Municipalities/ Municipal Corporations
7	ATREYAPURAM	15	3	17		
8	KOTHAPETA	10	70	10		
9	AMBAJIPETA	13	47	16		
10	AMALAPURAM	17	14	22	2	1
11	ALLAVARAM	14	19	21		
12	UPPALA GUPTAM	14	18	17		
13	AINAVILLI	17	50	21		
14	MUMMIDIVARAM	11	44	19		
15	KATRENI KONA	14	28	16		
16	I.POLAVARAM	11	32	14		
	Total	**214**	**449**	**275**	**2**	**1**

(Census, 2001)

This area is crisscrossed by the canal network of Central Godavari Delta Irrigation System. A total area of 84282ha (57.93%) is irrigated during kharif and 61216ha (47.07%) is irrigated during rabbi season by various sources of the irrigation. In these sources of irrigation, canal sources account for 51999ha (61.70%) during kharif and 51875ha (84.74%) during rabbi season. Tube wells and Filter points irrigate 32283ha (38.30%) and 9341ha (15.26%) during khariff and rabbi seasons respectively. (CPO, 2011)

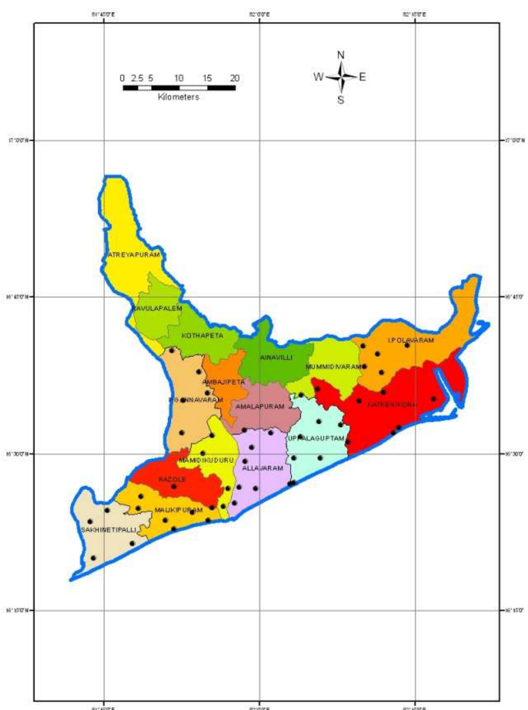


Figure 1: Administrative Divisions of the Study Area

Hydrometeorology

Climatologically, the area experiences dry, sub-humid, mega thermal climate with an oppressive summer and good seasonal rainfall. The south west monsoon sets in the second week of June and lasts till September end. October and

November receive rainfall from the northeast monsoon. The winter starts from December and lasts till mid February, followed by summer season up in early June. There are sixteen rain gauge stations in the area, one each at Mandal head quarters maintained by the Revenue Department. (CPO, 2011)

The normal annual rainfall in this area varies from a minimum of 1131.0mm at Kothapeta to a maximum of 1582.0mm at Sakhinetipalli and is depicted as Figure 2. The weighted average of normal rainfall of the area is 1343.77 mm. The distribution of annual rainfall during the years 2008, 2009 and 2010 are presented as Figure 3, Figure 4 and Figure 5.

During the year 2008, the annual rainfall varies from a minimum of 1054.4mm at Ravulapalem to a maximum of 1812.4mm at I. Polavaram. During the year 2009, the annual rainfall varies from a minimum of 540.0mm at P. Gannavaram to a maximum of 1007.0mm at Katrenikona and during the year 2010, the annual rainfall varies from a minimum of 1541.0mm at P. Gannavaram to a maximum of 2648.8mm at Amalapuram. The weighted average rainfall during the years 2008, 2009 and 2010 are 1499.38mm, 723.6mm and 2130.52mm respectively.

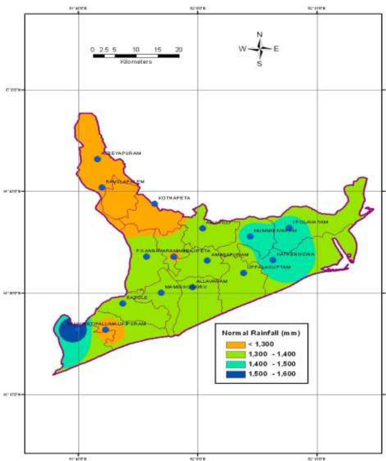
Aquifer Geometry

The aquifer mapping in the area was carried out by the Central Ground Water Board, which indicates the disposition of various aquifers in the area. The first aquifer, which is present up to a maximum of 34m below MSL is unconfined whereas the other aquifers are confined. The disposition of aquifers is as given below in Table 2. (CGWB, 2011)

Table 2: Disposition of Aquifers in the Study Area

S. No	Aquifer No.	Lithology	Type	From	To	Thickness
1	I	Sand	Unconfined	Ground Level	34m below MSL	10-34m
2	II	Sand	Confined	23m below MSL	63m below MSL	5 – 38m
3	III	Sand	Confined	61m below MSL	111m below MSL	6 – 38m

During the present study, Chemical Quality variation in the unconfined aquifer was studied by establishing 48 key observation wells in the area, all of which are tapping the unconfined aquifer. It was reported that the quality of ground water in the deeper aquifers is saline. The exploratory wells drilled in this area also indicate higher concentration of salts in the deeper aquifers. In the exploration conducted by the Central Ground Water Board during 2008-09 and 2009-10, two well fields were constructed in the area up to a depth of 100m bugle, which indicate the existence of three distinct aquifers less than 100m bgl. The first aquifer is under unconfined conditions, whereas the other two aquifers are confined in nature. (CGWB, 2009, 2010)



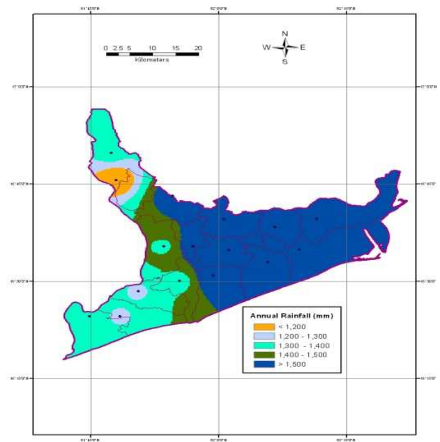
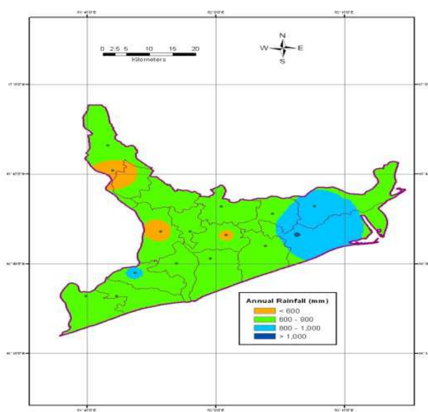


Figure 2: Normal Annual Rainfall **Figure 3: Annual Rainfall during 2008**



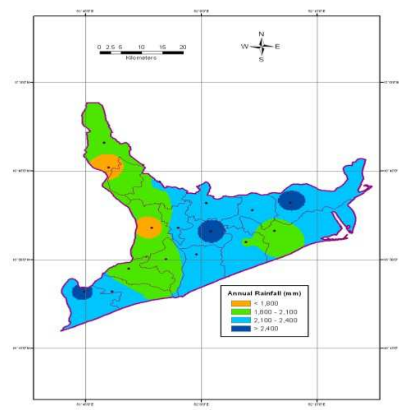


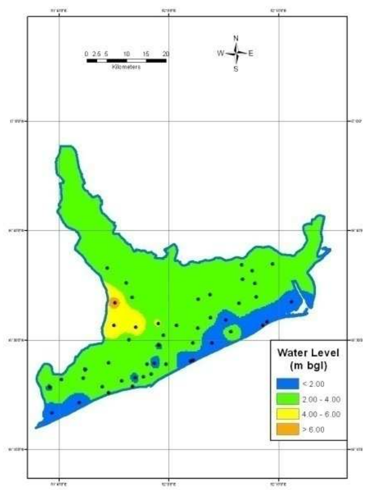
Figure 4: Annual Rainfall during 2009 **Figure 5: Annual Rainfall during 2010**

The ground water in the unconfined aquifer is tapped by open dug wells, and by filter points in the area as and when the need arises, because of the insufficient availability of surface water. The ground water in the deeper aquifers is not being tapped for Domestic or Irrigation uses as the quality of this water is saline. (CGWB, 2011)

Ground Water Levels

As a part of this study, the water levels in this area were monitored in the 48 key observation wells established in the area. During the Pre monsoon season in the year 2010, water levels in the area is in general in the range of 2-4m bgl except in small pockets where it is more than 4.0 m bgl near Lankala Gannavaram (Figure 6).

Depths of water levels during November, 2010 are mostly less than 1.0m except in the area near Lankala Gannavaram, where it is more than 2.0 m bgl (Figure 7).



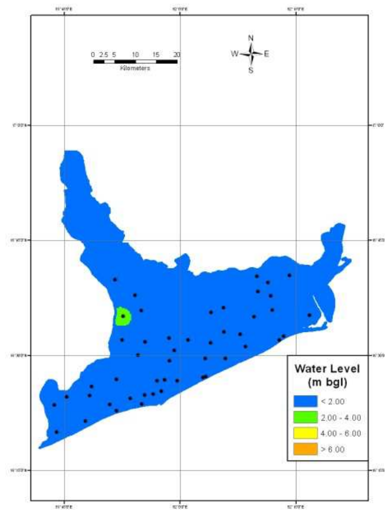


Figure 6: Depth to Water Level during May 2010 **Figure 7. Depth to Water Level during Nov 2010**

Ground Water Chemistry

The quality of ground water mostly depends on the lithological composition of various rock types through which the ground water passes. Ground water pollution can be caused by artificial sources like sewerage, organic & inorganic dumps and etc. As the area having proximity to the sea, it has a major cause for quality deterioration due to the hydraulic connectivity between the huge reservoirs of saline water i.e. sea and the aquifer system. To study the general quality in the area and any influence and/or impact of the sea water, ground water samples were collected from key observation wells during May 2008 and January 2011 and studied.

Distribution of Electrical Conductivity

The Electrical conductivity is defined as the reciprocal of electrical resistance, and it measures the ability of water to conduct electric current. It is an index of mineralization in ground water. BIS prescribes 500 mg/l of Total Dissolved Solids as desirable limit and 2000 mg/l as maximum permissible limit in the absence of any alternate source (BIS, 1991). These limits correspond to 750 and 3000 µs/cm at 25° of electrical conductivity respectively. The electrical conductivity measured in a field during the study periods, which are used for understanding the temporal variations in the quality of the area. The electric conductivities measured from the field as well as in the laboratory are provided in Table 3.

The field Electrical conductivity during pre monsoon 2008 in most of the area is under 3000 µs/cm at 25° except at N. Kothapalli. The area near the coast mostly shows an Electrical conductivity less than 1500 µs/cm at 25° and is presented as Figure 8. During Post Monsoon Season it is well within 3000 µs/cm at 25° in the entire area and near the coast, it is less than 1500 µs/cm at 25°. The Electrical conductivity distribution during post monsoon 2008 is presented as Figure 9.

Even though in most of the area, the Electrical conductivity during pre monsoon 2009, is under 3000 µs/cm at 25° some area in Uppalaguptam and Katernikona mandals near the coast has shown values of higher order. This situation along the coast indicates some amount of stress on the ground water reservoir due to which, the Ghyben-Hertzberg surface started moving towards land and is presented as Figure 10. During Post Monsoon Season, it is well within 3000 µs/cm at 25° in the entire area, and except in small areas, where it is more than 3000 µs/cm at 25°. The Electrical conductivity

distribution during post monsoon 2009 is presented as Figure 11.

Table 3: Distribution of Electric Conductivity of Ground Water in Central Godavari Delta

S. No	Well No	Village	Electric Conductivity In Micro Siemens/Cm At 25°C							
			2008		2009		2010		LAB	
			May	Nov	May	Nov	May	Nov	Pre	Post
1	RHS-01	G.Vemavaram	930	920	890	1136	860	1810	970	
2	RHS-02	I.Polavaram	940	560	710	3333	840	560	1050	781
3	RHS-03	Kesanakurru	840	960	860	1263	1340	1470	750	1087
4	RHS-04	Tillakuppa	2520	1670	2380	3333	840	1720	2590	2750
5	RHS-05	Muramalla	1270	1080	1400	3333	2580	1140	1390	2600
6	RHS-06	Cheyyeru	1300	1090	1020	1987	1420	960	1460	1360
7	RHS-07	Katrenikona	1950	1350	1330	1639	1610	440	2200	1560
8	RHS-08	Pallamkurru	2630	3370	2620	3333	3070	3200	3290	3230
9	RHS-09	N.Kothapalli	8080	3350	8010	3333	7900	6480	11530	8698
10	RHS-10	Uppalaguptam	1160	810	1190	1287	1820	1210	1425	1740
11	RHS-11	Bhimanapalli	370	690	380	1279	380	830	379	310
12	RHS-12	Kunavaram	2720	2970	2850	3333	3300	3470	3065	3080
13	RHS-13	Challapalli	710	200	2080	3333	2410	960	855	2200
14	RHS-14	Allavaram	2400	1330	2390	3333	2730	1380	2200	2600
15	RHS-15	Godi Lanka	2090	1870	2050	1908	2060	2360	2350	1870
16	RHS-16	Bendamuru Lanka	470	890	460		640	1240	385	560
17	RHS-17	Gudala	1750	1800	2390	3333	2020	2220	2100	1940
18	RHS-18	Bodusukurru	940	950	850	1012	1110	1110	690	930
19	RHS-19	Munganda	1130	560	1170	1030	1450	590	995	1300
20	RHS-20	Narendra Puram	2040	340	1840	1133	1880	650	1800	1636
21	RHS-21	G.Pedapudi	1890	1540	2030	1386	2280	2000	2345	2110
22	RHS-22	Lankala Gannavaram	1450	1350	1630	1582	1810		1175	1746
23	RHS-23	Nagullanka	820	880	1000	1017	840	1270	595	622
24	RHS-24	Nagaram	3380	3330	2900	3333	2570	2530	4150	2570
25	RHS-25	Appanapalli	1230	1280	1460	1390	1380	1190	1050	1020
26	RHS-26	Goganna Matham	2080	1330	2040	3333	2410	1700	2330	2380
27	RHS-27	Chintalapalli	1570	260	1010	981	1540	150	1240	1240
28	RHS-28	Kesana Palli	1150	780	830	1355	1440	890	1380	1270
29	RHS-29	Sankara Guptam	1180	1060	1000	1435	20000	1460	1373	1320
30	RHS-30	Kesava Dasu Palem	4470	2960	2830	3333	1540	2480	5555	1670
31	RHS-31	Antarvedi	2590	2430	2580	3333	1680	1870	3040	1700
32	RHS-32	Rameswaram	560	790	610	870	720	850	580	670
33	RHS-33	Sakhinetipalli	820	730	1020	1413	970	450	750	835
34	RHS-34	Malikipuram	950	950	780	1054	1060	960	805	954
35	RHS-35	Gudimellanka	2350	2460	2710	3333	2650	2890	2580	2710
36	RHS-36	S.Yanam		3333	13220	3333	4250	330	19820	4430
37	RHS-37	Rameswaram		3333	12110	3333	3720	5720	4500	3920
38	RHS-38	Vasala Tippa		2000	2680	3333	3030	1750	2350	3110
39	RHS-39	Komaragiri Patnam		935	1300	1495	1740	1020	930	1760
40	RHS-40	Gachakayala Pora		3333	6630	1267	4770	770	3040	5230
41	RHS-41	Kandi Kuppa		1339	1380	3333	13570	750	1220	16400
42	RHS-42	Nila Revu		333	400	653	650		320	608
43	RHS-43	Brahmasamadheyam		365	700	968			366	
44	RHS-44	Karavaka		1211	1260	1657	1530	1400	1210	1490
45	RHS-45	Gollapalem		3333	6060	3333	9500	1690	7110	10800
46	RHS-46	Toorpupalem		3333	3850	3333	5670	2380	3865	6476
47	RHS-47	Dindi Beach Road		3333	7800	3333	20000		5800	40220
48	RHS-48	Vodala Revu		1169	1800	3333	2740	1010		3200
		Maximum	8080	3370	13220	3333	20000	6480	19820	40220

S. No	Well No	Village	Electric Conductivity In Micro Siemens/Cm At 25°C							
			2008		2009		2010		LAB	
			May	Nov	May	Nov	May	Nov	Pre	Post
		Minimum	370	200	380	653	380	150	320	310
		Mean	1792	1588	2510	2245	3283	1621	2573	3493
		Standard Deviation	1411	1048	2766	1057	4299	1253	3291	6248

The Electrical conductivity during pre-monsoon 2010 is under 3000 µs/cm at 25° except in some areas in Malikipuram, Katrenikona mandals near the coast, which have shown higher values. The distribution of Electrical conductivity is presented as Figure 12. During Post Monsoon Season it is well within 3000 µs/cm at 25°in the entire area. The Electrical conductivity distribution during post monsoon 2010 is presented as Figure 13.

The distribution of Electrical conductivity of the samples collected from the key wells and analyzed at the laboratory has been presented in Figure 14 and Figure 15. This Electrical conductivity also shows that some area in Uppalaguptam, Sakhinetipalli and Allavaram mandals have higher values of more than 3000 µs/cm at 25° during pre monsoon, and similarly some areas in Katrenikona, Uppalaguptam and Malikipuram mandals have shown higher values during post monsoon season the also.

Temporal Variation in Chemical Quality in Terms of Electric Conductivity

Perusal of the table indicates that there is a conspicuous change in the quality of ground water during various seasons. Especially, the electric conductivity during the pre monsoon season is more than that of the post monsoon season. In some situations, even in the pre-monsoon season, the electric conductivity is much higher than that of the previous pre monsoon seasons. If the electric conductivity of samples during pre monsoon 2008 are compared with that of post monsoon 2008, there are only 23 samples shown decrease in electric conductivity, whereas 11 samples shown an increase and one sample has maintained status quo. Normally, during post monsoon season samples should show lesser conductivity because of dilution by recharge. Similarly 33 samples showed an increase in electric conductivity whereas only 15 samples shown decrease during the year 2009. During the year 2010, 15 samples have shown deterioration of quality, whereas 30 out of 45 samples collected shown improvement. Perusal of the figures indicates the deterioration of the quality is more conspicuous in the near coastal areas.

One of the main visible reasons for the deterioration of water quality is deficit rainfall during the year 2009. The area received only 50% of normal rainfall during that monsoon. The entire area is a crop intensified area with the Godavari barrage canal network. Because of the 50% deficit rainfall, the farmers in the area, have to depend on ground water, which is easily accessible through filter points of depth not more than 20m.The perusal of the electrical conductivity in the samples collected from Kandikuppa, S. Yanam, Rameswaram, N. Kothapalli, Gollapalem indicate the same situation. The electric conductivity of the sample from Kandikuppa changed from 1339 µs/cm at 25°in the month of November, 2008 raised up to 13570 µs/cm at 25° in the month of May 2010, which was once again reached the minimum of 750 µs/cm at 25°during November, 2010 which was an excess rainfall year. This well, approximately 2kms from the coast and being in the tail ends of the canal, commands the farmers in the surroundings, to extract water from the coastal aquifers through filter points.

Ground water in the coastal aquifers exists in hydraulic connectivity with the sea water. Hence, the situation is very delicate and requires a precise management strategy to obstruct the sea water intrusion or upcoming, which will either permanently or temporarily deteriorate the ground water quality in the aquifer or in the wall. All these possibilities of this

type of pollution are inadvertently from the activities of human beings. Normally, the natural flow of ground water is towards the sea, with the decreasing head towards the sea. As long as there is no ground water abstraction in any coastal aquifer, the hydraulic gradient is maintained at the maximum and the fresh water discharges into the sea are at the maximum. Once the human activity of ground water withdrawal starts, the hydraulic head starts decreasing, which result in the decrease of the fresh ground water discharges into the sea. The situation induces the fresh water - saline water interface starts its journey towards the land. Depending on the quantum of abstraction, Fresh water head above mean sea level and the upcoming effect interferes with the quality of the water being pumped. When the withdrawal increases abundantly, the hydraulic head diminishes to a situation, when the reversal of hydraulic gradient occurs making the aquifer saline.

The unconfined aquifer in this area is up to 34m below MSL and the ground water in this aquifer is fresh excepting small pockets. The Field electrical conductivity measured at the time of monthly monitoring of water levels indicate the increase of electric conductivity near Dinda, N. Kothapalli, Kandikuppa, S. Yanam, Gollapalli during the water stress months, indicating the rise of the transition zone of fresh water – saline water interface, due to abstraction of ground water in this area for the purpose of Irrigation. Hence there is a need for proper monitoring of the saline water - Fresh water interface in the area, by establishing a purpose built piezometers with predefined monitoring parameters of level and quality, with reference to the depth.

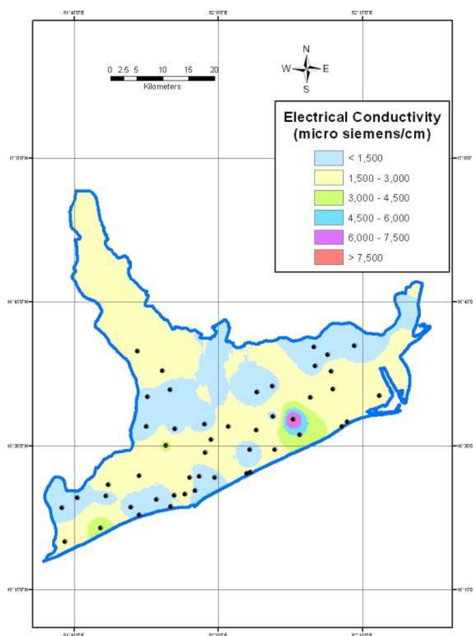


Figure 8: Distribution of Field Electric Conductivity During Pre Monsoon 2008

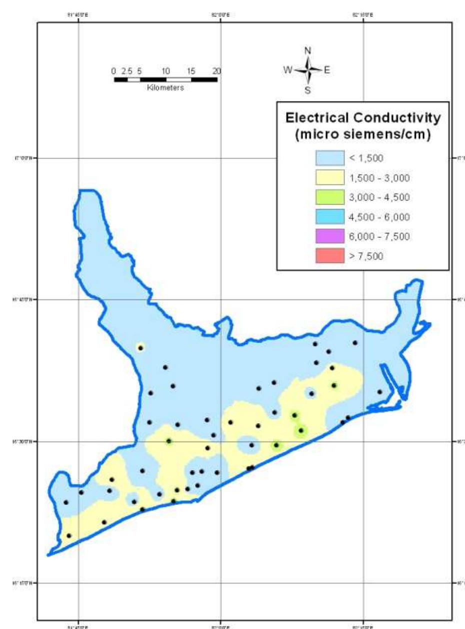


Figure 9: Distribution of Field Electric Conductivity During Post Monsoon 2008

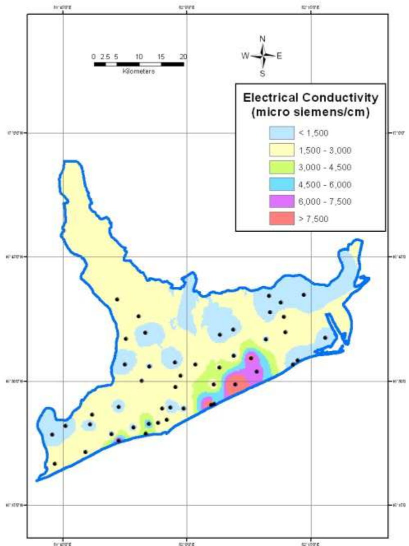


Figure 10: Distribution of Field Electric Conductivity During Pre Monsoon 2009

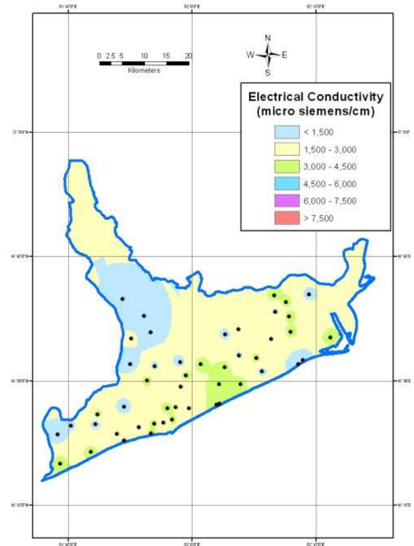


Figure 11: Distribution of Field Electric Conductivity During Post Monsoon 2009

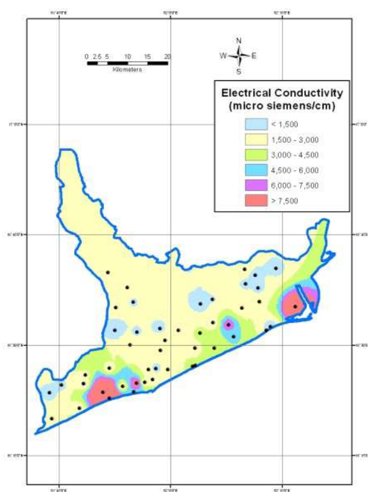


Figure 12: Distribution of Field Electric Conductivity During Pre Monsoon 2010

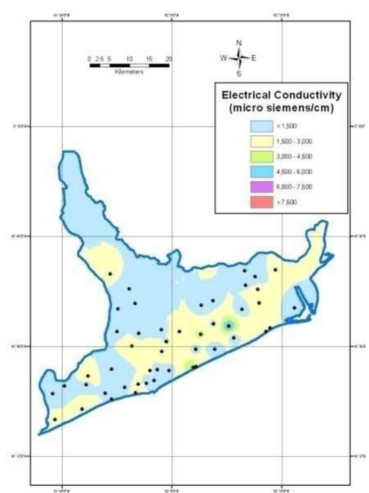


Figure 13: Distribution of Field Electric Conductivity During Post Monsoon 2010

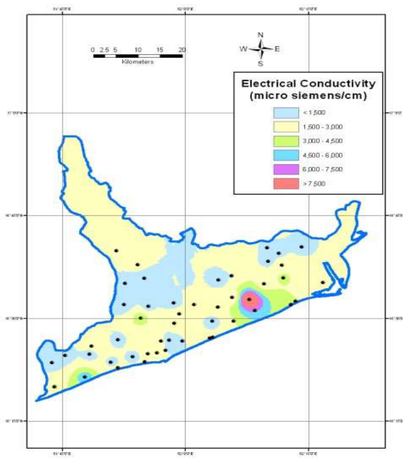


Figure 14: Distribution of Laboratory Electric Conductivity During Pre Monsoon

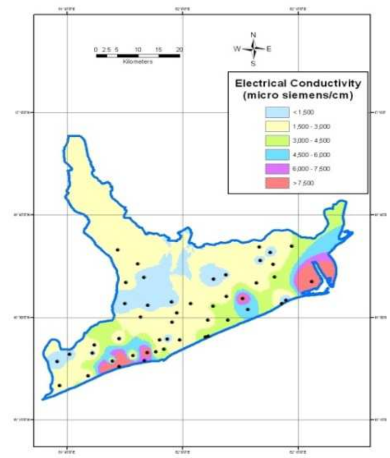


Figure 15: Distribution of Laboratory Electric Conductivity During Post Monsoon

CONCLUSIONS

Due to the less availability of surface water either in the form of rainfall, or in the form of canal water in the tail ends, farmers use ground water through filter points. Because of the ground water abstraction in the area, the fresh water - saline water interface was disturbed and the quality of ground water was deteriorated in the water stress periods. Even though, in the present study it was observed that the quality attains its normal values in the excess rainfall years, there is a possibility of irreversible deterioration in the future. Hence, there is an urgent need for monitoring the fresh water - saline water interface by constructing a purpose built observation wells, with predefined monitoring parameters of level and quality with reference to depth, and assess the interface on a regular basis and prepare more robust ground water management plans for this area.

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